UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
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OFFICE OF
WATER AND
WATERSHEDS

MEMORANDUM August 16, 2016~~June 10, 2016~~

SUBJECT: Results of CORMIX Modeling of the Clearwater Paper Lewiston Mill Discharge through Outfall 001 for water quality criteria for toxic pollutants

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Administrative Record for Clearwater Paper Lewiston Mill, Permit #ID0001163

1 Introduction

Version 9.0GTD of the CORMIX Mixing Zone Expert System (CORMIX) was used to evaluate the mixing properties of the discharge from the Clearwater Paper Lewiston Mill for the purpose of determining regulatory mixing zones for toxic pollutants.

2 Description of Receiving Waters and Discharge

2.1 Receiving Water

Effluent from the Clearwater Paper Lewiston Mill discharges through outfall 001 to the Snake River at its confluence with the Clearwater River, near the head of Lower Granite Pool. The outfall is located at latitude 46° 25' 31" N, and longitude 117° 02' 15" W (approximately river mile 140).

The discharge location is at the nexus of three 8-digit hydrologic units. It is at the downstream ends of both the Lower Snake-Asotin watershed (17060103) and the Clearwater watershed (17060306). It is at the upstream end of the Lower Snake-Tucannon watershed (17060107).

2.1.1 Mixing Properties of the Snake and Clearwater Rivers

Mixing of the Snake and Clearwater Rivers at the confluence is complex. As described in *Hydraulic Characteristics of the Lower Snake River During Periods of Juvenile Fall Chinook Salmon Migration* (Cook et al. 2006), circulation patterns at the confluence are driven by the temperatures and discharge rates of the Snake and Clearwater Rivers, and three general patterns are observed.

When the temperatures as well as the discharge rates of the two rivers are similar, the two rivers flow parallel to each other, with little mixing occurring between the two rivers for several miles downstream from the confluence.

When there is a small difference in temperature but a large difference in discharge rates between the two rivers, the two rivers will mix together within a short distance downstream of the confluence.

When there is a large difference in temperature between the two rivers, the colder Clearwater River plunges beneath the warmer Snake River at the confluence, creating a vertically stratified temperature profile. During July and August, the Clearwater River is significantly cooler (10 degrees or more) than the Snake River, and the resulting density difference is sufficient to stratify Lower Granite Reservoir. This vertical stratification due to large temperature differences occurs over a wide range of discharge rates.

The EPA represented these varying conditions in the modeling as described in Section 4.1.2, below.

2.2 Outfall 001

The effluent is released through outfall 001 from a 400-foot long diffuser. The depth of the water at the discharge point is approximately 30 feet. The diffuser is in waters of the state of Idaho and upstream of the Idaho-Washington state line by 191 meters. The diffuser consists of 80 individual ports spaced 5 feet apart rising from a common, buried 48-inch outfall pipe. Each riser pipe is angled 30 degrees from horizontal with the exit port about 1.5 feet above the river bottom. Each riser pipe is 3 inches in diameter. Only 72 of the 80 ports are currently operating.

3 Idaho's Mixing Zone Policy

A number of provisions of Idaho's mixing zone policy (IDAPA 58.01.02.060) are potentially applicable to Clearwater Paper's discharge of toxic pollutants, including:

- Mixing zones, individually or in combination with other mixing zones, shall not cause unreasonable interference with, or danger to, beneficial uses. Unreasonable interference with, or danger to, beneficial uses includes, but is not limited to, the following:
  - Impairment to the integrity of the aquatic community, including interfering with successful spawning, egg incubation, rearing, or passage of aquatic life.
  - Bioaccumulation of pollutants (as defined in Section 010) resulting in tissue levels in aquatic organisms that exceed levels protective of human health or aquatic life.
  - Lethality to aquatic life passing through the mixing zone.
- Multiple nested mixing zones may be established for a single point of discharge, each being specific for one (1) or more pollutants contained within the discharge.
- The width of a mixing zone is not to exceed twenty-five percent (25%) of the stream width.
- The mixing zone shall not include more than twenty-five percent (25%) of the low flow design discharge conditions as set forth in Subsection 210.03.b. of these rules.

Different mixing zone restrictions apply in lakes and in reservoirs with a mean detention time greater than 15 days (IDAPA 58.01.02.060.h.ii and iii). Detention time is defined in the Idaho Water Quality Standards as the mean annual storage volume divided by the mean annual flow out of the reservoir for the same period (IDAPA 58.01.2.060.01.h.iv). Using the mean annual flow measured downstream from the Lower Granite Dam, at USGS station number 13343600, for a low flow year (42,380 CFS, during water year 1979) and the full pool storage of the reservoir (483,800 acre-feet), .the detention time of Lower Granite Pool is 5.8 days. Thus, Lower Granite Pool is not considered a reservoir for the purpose of Idaho's mixing zone policy (IDAPA 58.01.2.060.01.h.iv).

In addition, mixing zones must be sized so that they do not extend into waters of the state of Washington, downstream.

4 Cormix Modeling

The EPA used the Cormix model to evaluate the mixing properties of the discharge. Cormix is a comprehensive software system for the analysis, prediction, and design of outfall mixing zones resulting from discharge of aqueous pollutants into diverse water bodies.

A screening analysis was performed in order to evaluate the effect upon mixing of the variability in ambient temperatures and, in turn, densities (including ambient temperature stratification) throughout the year. At least one model simulation was set up for each month. Multiple simulations were set up for July through October, to reflect different ambient temperature stratification conditions that have been observed during July and September and to investigate the effect of changes in effluent temperature (and therefore density) upon plume behavior in a stratified ambient density field during these months. The simulation producing the poorest mixing in the screening analysis was then adapted for use sizing the mixing zones.

4.1 Model Inputs

The Cormix model inputs and their bases are described below.

4.1.1 Effluent Tab

The effluent flow rate was set at 38 million gallons per day, which is the maximum daily effluent flow rate reported by the facility between May 2005 and February 2016.

The effluent temperature was used to specify the effluent density. In general, the effluent temperature was set equal to the applicable temperature limit for the month.

For scenarios in which the ambient temperature is vertically stratified (late July – October), the EPA also ran Cormix scenarios with the effluent temperature set equal to the average temperature reported for the month. Specifying a lower ambient temperature increases the density of the discharge and can change the way the plume interacts with a stratified ambient density field. These average effluent temperatures were:

- 29.0 °C in July
- 28.0 °C in August
- 26.7 °C in September
- 25.8 °C in October.

With the exception of August, specifying the average effluent temperature instead of the effluent temperature limit caused no significant differences in the plume's behavior. As described in Section 4.1.2.1, below, the plume behavior in August is sensitive to the effluent temperature.

4.1.2 Ambient Tab

4.1.2.1 Ambient Width and Depth

The EPA specified the same width and depth for all simulations. The width and depth are consistent with cross section 139.22, located just downstream from the discharge, as shown in *Appendix M: Results of Hydrology Studies: 1992 Reservoir Drawdown Test Lower Granite and Little Goose Dams* (USACE 1993). Both the average depth and the depth at the discharge were specified as 9.14 meters (30 feet). The river was represented as a bounded channel with a width of 610 meters (about 2000 feet).

In general, it is appropriate to use a cross-section located somewhat downstream from the discharge to schematize the river channel, because the Cormix model will account for any interactions with the stream bank or bottom, and these interactions will occur downstream from the point of discharge.

The Cormix model allows the user to specify a vertically stratified ambient density. Thus, the vertically stratified ambient density observed when the Clearwater River flow plunges below the Snake River flow can be represented directly in the model. The model will then determine whether a positively buoyant plume (such as the plume created by the Clearwater Paper discharge) will "trap" at an intermediate depth at which it reaches a density equal to the ambient density, or break through the stratified ambient density field and reach the water surface.

In this analysis, in general, the Cormix model predicted that the positively buoyant discharge would reach the water surface after a short distance, even when the ambient temperature is stratified. The sole exception to this behavior was observed in the August simulation. In August, if the effluent temperature is set equal to the effluent temperature limit of 31 °C, the plume will break through the stratification and reach the surface within a short distance. However, if the effluent temperature is set equal to the average effluent temperature reported in August (28.0 °C), the plume will be confined to the lower layer of the river by the ambient stratification.

Cormix does not have an option to specify a horizontally stratified ambient temperature, such as that which occurs when the two rivers flow parallel to each other downstream from the confluence. However, the EPA believes it is more realistic to represent the entire cross-section of the river in the model, even during horizontally stratified conditions, instead of modeling the discharge as if the river is only as wide as the Snake River upstream from the discharge, as was done in the "Temperature Assessment for the Potlatch Mill Discharge through Outfall 001," (2005 Temperature Assessment) (Koch and Nickel 2005).

As explained in Section 3, above, one the mixing zone restrictions is that the width of a mixing zone is not to exceed twenty-five percent (25%) of the stream width. Thus, it is important to specify a realistic river cross-section so that the Cormix model can accurately determine the boundaries of a mixing zone specified as a percentage of the river's width and report the plume characteristics the boundary of such a mixing zone.

In addition, the Cormix model accounts for plume interactions with the stream bank. When the Cormix model predicts that the plume has contacted the stream bank, it will abruptly shift the plume centerline to the contacted bank. The model will also assume that there is no more ambient water available for entrainment on the side of the plume which has contacted the bank, as the plume proceeds downstream, thus slowing mixing.

While, under some conditions, the Snake and Clearwater rivers flow side-by-side, with little mixing occurring between the two rivers' flows for several miles, the EPA does not believe it is realistic to represent the "boundary" between the two rivers' flows in the Cormix model as a stream bank, as was done in the 2005 Temperature Assessment, since it is not a solid physical boundary that will prevent entrainment of ambient water.

However, the EPA has nonetheless considered the potential for horizontal stratification of the Snake and Clearwater River flows when specifying the upstream temperature, as described below.

4.1.2.2 Temperature and Stratification

The EPA characterized the ambient density using temperature. The ambient temperatures specified in the model are always based on actual measurements.

4.1.2.2.1 Late July – October: Vertical Stratification

From late July – October, the EPA estimated the vertically stratified ambient temperature profile from the chart of the observed temperature profile for the summer of 2003, at "Site 7," in Appendix A to *Hydraulic Characteristics of the Lower Snake River During Periods of Juvenile Fall Chinook Salmon Migration* (Cook et al. 2006). Site 7 was the closest ambient temperature monitoring location to the discharge. It was located about 268 meters downstream from the outfall, near the south bank of the Snake River, which is the bank nearer to the discharge location. From mid-July through the end of data collection in mid-October 2003, the ambient temperature was vertically stratified.

4.1.2.2.2 November – Early July: No Vertical Stratification

From November through early July, the EPA specified a uniform (unstratified) ambient temperature.

In early July, the temperature was estimated from the chart of the observed temperature profile for the summer of 2003, at "Site 7" in Appendix A to *Hydraulic Characteristics of the Lower Snake River During Periods of Juvenile Fall Chinook Salmon Migration*. The ambient temperature was not vertically stratified at this location in early July.

From November through June, the ambient temperature was based on USGS NWIS data for the Snake and Clearwater rivers, from USGS stations 13334300 and 13342500, respectively. During this time, the temperatures of the Snake and Clearwater rivers are similar, so no significant vertical temperature stratification will occur. However, horizontal stratification may occur.

As explained in Section 2.1, above, when the temperatures of the two rivers are similar, mixing properties at the confluence are determined by the relative flow rates of the two rivers.

When the flow rates of the two rivers are similar, water from the Snake and Clearwater Rivers flows in parallel, with little mixing occurring between the two rivers for several miles downstream of the confluence, and with water from the Clearwater River attached to the north bank and water from the Snake River attached to the south bank. Since the diffuser is located nearer to the south bank, near field mixing of the Clearwater Paper discharge will be primarily with water from the Snake River under these conditions. This mixing scenario is described in Section 4.2.1 of *Hydraulic Characteristics of the Lower Snake River During Periods of Juvenile Fall Chinook Salmon Migration*. This type of mixing was observed on April 4, 2002, when the ratio of the Clearwater River flow to the Snake River flow was 0.86 (i.e., the flow rate of the Clearwater River was 86% of the flow in the Snake River).

When the flow rates of the two rivers are dissimilar, the two rivers will mix relatively quickly near the confluence. Thus, under these conditions, near field mixing of the Clearwater Paper discharge will be with a mixture of water from the Snake and Clearwater Rivers. This mixing scenario is described in Section 4.2.2 of *Hydraulic Characteristics of the Lower Snake River During Periods of Juvenile Fall Chinook Salmon Migration*. This type of mixing was observed on May 24, 2003, when the ratio of the Clearwater River flow to the Snake River flow was 0.65.

A threshold flow ratio at which mixing properties change between these two types has not been identified. However, the EPA believes it is reasonable to assume, based on the examples described above, that, if the ratio of the Clearwater River flow to the Snake River flow is 0.65 or lower (i.e., the flow of the Clearwater River is less than or equal to 65% of the flow of the Snake River), the two rivers will mix at the confluence, since this mixing behavior has been observed at this flow ratio. If the ratio of the Clearwater River flow to the Snake River flow is greater than 0.65, then the EPA has assumed that the two rivers will flow parallel to each other for a significant distance downstream.

The EPA has therefore estimated the upstream temperature at the Clearwater Paper outfall from November – June as follows.

If the ratio of the Clearwater River flow to the Snake River flow is 0.65 or lower, the EPA has calculated the upstream temperature as the mixture of the temperatures of the Snake and Clearwater rivers. That is to say, the EPA has assumed that the two rivers mix immediately at the confluence under these conditions.

If the ratio of the Clearwater River flow to the Snake River flow is greater than 0.65, then the EPA has assumed that the upstream temperature is the temperature of the Snake River (with no influence from the Clearwater River). That is to say, the EPA has assumed that no significant mixing of the two rivers will occur near the outfall under these conditions.

The EPA estimated an upstream temperature as described above for each day for which both flow and temperature data were available from USGS NWIS for both rivers, from January 1, 2000 through September 30, 2015. The EPA then calculated the 90th percentile of these estimated temperatures for each month, and used those monthly 90th percentile values as the upstream temperature, from November – June.

The EPA believes this is a reasonable (although idealized) characterization of the ambient temperatures (and, in turn, densities) for this period of time.

4.1.2.3 Ambient Velocity

The EPA specified the monthly critical low flows as the flow rates; the velocity was automatically calculated from the flow rates and the area of the schematized river cross section. The critical low flow rates were calculated from the sum of the flow rates of the Snake and Clearwater Rivers, from USGS stations 13334300 and 13342500, respectively.

4.1.2.4 Wind Speed

The wind speed was specified as 2 meters per second (4.5 miles per hour). This is the value recommended by the Cormix user manual as a conservative estimate, when field data are not available (Doneker and Jirka 2014).

4.1.2.5 Roughness

The EPA specified a Manning's "n" of 0.025 because it is the appropriate factor to use for an earthen channel with some stones and weeds, according to Table 4.3 of the Cormix user manual (Doneker and Jirka 2014).

4.1.3 Discharge Tab

The EPA selected the "CORMIX2" option because Clearwater Paper's effluent is discharged through a multiport diffuser.

The nearest bank is on the left, from the perspective of an observer looking downstream (i.e., the southern shore of the Snake River in Clarkston, WA). The EPA estimates that the near end of the diffuser is 183 meters from the bank, and the far end is 274 meters from the bank.

The diffuser length is the length from one diffuser end point (first nozzle/port) to the other endpoint (last nozzle/port). The Potlatch Mill diffuser length is 122 meters as reported in the 1997 Potlatch Mixing Zone Study and from Potlatch documents of the diffuser design.

The port height is the height of the discharge port centers above the bottom of the river. This value is 0.45 meters based on Potlatch diffuser design documents and the 1997 Potlatch Mixing Zone Study.

The port diameter is the average diameter of all ports/nozzles in this diffuser. This value is 0.0762 meters (3 inches) based on Potlatch diffuser design documents and the 1997 Potlatch Mixing Zone Study.

The contraction ratio is a coefficient that describes the shape of the port/nozzle. This can range from 1 for well-rounded ports to 0.6 for sharp-edged ports. A default value of 1.0 is used if the user does not know the actual contraction ratio. The value used for this discharge is 0.8 based on the 1997 Potlatch Mixing Zone Study.

The total number of openings is the total number of ports/nozzles for this diffuser. While the diffuser is designed with 80 ports, there are only 72 active ports based on a 1997 dive survey; therefore, EPA used 72 as the value in the model.

The alignment angle gamma is the difference between the diffuser line and the ambient current measured counterclockwise from the ambient current direction. This value is 48 degrees based on aerial photos (Potlatch and IDEQ) and Potlatch diffuser design documents.

The nozzles per riser option allows the choice between 1) individual single ports (holes) or single nozzles attached to the diffuser, 2) two nozzles or ports per riser, or 3) several nozzles or ports per riser. Since the Potlatch diffuser has a single nozzle, EPA has chosen the "Single" nozzle per riser option. This was based on Potlatch diffuser design documents and the 1997 Potlatch Mixing Zone Study.
The "Orientation of Ports or Nozzles" option allows the choice between a unidirectional arrangement and an alternating arrangement. The unidirectional arrangement is where all the ports/nozzles point, more or less, into the same, mostly horizontal, direction. The alternating arrangement is where every other port/nozzle points into the opposite direction or all point directly upward in the vertical direction. Since the Potlatch diffuser nozzles are arranged so that they point in the same direction, EPA chose the "Unidirectional" nozzle arrangement option. This was based on Potlatch diffuser design documents and the 1997 Potlatch Mixing Zone Study.

The horizontal angle (sigma) is the horizontal angle measured clockwise from the ambient current direction to the average port/nozzle centerline direction. Zero degrees represent all ports/nozzles pointing in the downstream direction in a co-flowing direction with the current and 90 degrees represents all ports/nozzles pointing perpendicular to, and to the left of, the ambient flow facing downstream in the current direction. This value is 318 degrees based on Potlatch diffuser design documents and the 1997 Potlatch Mixing Zone Study.

The relative orientation angle (beta) is the nearest angle between the horizontal projection of the average port/nozzle centerline direction and the diffuser axis. Zero degrees represent all ports/nozzles oriented along the diffuser line (staged diffuser) and 90 degrees represents all ports/nozzles oriented normal to the diffuser line (unidirectional diffuser). This value is 90 degrees based on Potlatch diffuser design documents and the 1997 Potlatch Mixing Zone Study.

The nozzle direction option allows the choice between all ports/nozzles pointing in the same direction and the ports/nozzles arranged in a variable fanned-out orientation. EPA chose all nozzles pointing in the "same direction" option based on Potlatch diffuser design documents and the 1997 Potlatch Mixing Zone Study.

4.1.4 Mixing Zone Tab

The mixing zone was specified as 25% of the channel width (IDAPA 58.01.02.060(h)(i)(1)). If this resulted in a mixing zone extending more than 191 meters in the downstream direction, the mixing zone was specified as a distance of 191 meters downstream from the discharge.

The water quality standard is specified as a toxic parameter.

4.2 Model Results

4.2.1 Monthly Screening Analysis

Model results from the monthly screening analysis, as well as mass balance calculations for 25% of the 7Q10 flow for each month, are summarized in Table 1.

Table 1: Cormix Model Results: Monthly Screening

Month	Ambient T (°C)	Effluent T (°C)	7Q10 River Flow (CFS)	Calculated Ambient Velocity (ft/s)	Dilution Factor at 25% of Stream Flow Volume (mass balance)	Dilution Factor at 25% of Stream Width or at Washington Border[2]
January	4.4	33	18,100	0.302	78.0	48.3
February	4.8	33	19,700	0.328	84.8	49.4
March	7.9	33	22,400	0.373	96.2	53.7
April	11.1	33	34,800	0.580	149	72.7
May	13.2	33	54,100	0.902	231	97.8
June	18.3	33	34,400	0.573	147	71.1
Early July	20.0	32	26,600	0.433	114	60.7
Late July	13.5 – 22.5	32				60.6
August (limit)	13.8 – 22.8	31	19,800	0.330	85.2	49.6
August (avg.)		28				39.2
Early Sep.	13.5 – 21.0	31	16,200	0.270	69.9	47.7
Late Sep.	15.5 – 19.0	31				47.7
October	15.5 – 18.5	33	15,500	0.258	66.9	47.5
November	9.9	33	16,400	0.273	70.7	47.8
December	5.8	33	15,700	0.261	67.8	47.6

Notes:

1. The ambient temperature is stratified from late July – October. The ambient temperature is listed as a range between the temperature at the bottom of the river (cooler) and the surface (warmer).
2. During April, May, and June, a mixing zone encompassing 25% of the stream width would extend downstream past the Washington border. The State of Idaho cannot authorize a mixing zone that extends into another State. Thus, the conditions at the Washington border (191 meters downstream) are reported for April, May and June.

As shown in Table 2, above, the Cormix model predicts that the poorest mixing will occur in August and when the effluent is near the average effluent temperature for the month, as opposed to the temperature limit. Under these conditions, the ambient temperature is strongly vertically stratified, and the effluent plume will “trap” below the thermocline.

This reduces the dilution that would occur at the boundary of a mixing zone encompassing 25% of the width of the river, relative to the scenario using the effluent limit of 31 °C as the effluent temperature, in which the plume quickly reaches the surface. Specifically, in the effluent limit scenario, Cormix predicted that a dilution factor of 49.6:1 would be achieved at the boundary of a mixing zone encompassing 25% of the stream width. In the average effluent temperature scenario, the dilution factor at the boundary of a mixing zone encompassing 25% of the stream width was only 39.2:1.

4.2.2 Detailed Analysis of August Mixing Conditions

Having identified August conditions with the average effluent temperature as the critical condition for mixing, the EPA ran additional modeling scenarios with the flow rates specified in IDAPA 58.01.02.210.03.b to evaluate mixing properties for acute and chronic aquatic life water quality criteria and for human health criteria for carcinogens and non-carcinogens.

4.2.2.1 Width and Volume Restrictions

Modeling results evaluating conditions at 25% of the stream width, as well as mass balance calculations for 25% of the critical stream flow volumes, are summarized in Table 2, below.

Table 2: Cormix Model Results for August Conditions

Criteria Type	River Flow Statistic	River Flow Value (CFS)	Calculated Ambient Velocity (ft/s)	Dilution Factor at 25% of Stream Flow Volume (mass balance)	Dilution Factor at 25% of Stream Width[1]
Acute Aquatic Life[2]	1Q10	17,700	0.295	76.3	38.6
Chronic Aquatic Life	7Q10	19,800	0.330	85.2	39.2
Human Health Non-Carcinogen	30Q10	22,900	0.413	98.4	41.5
Human Health Carcinogen[1]	Harmonic Mean	32,600	0.543	140	48.5

Notes:

1. In the harmonic mean scenario, a mixing zone encompassing 25% of the stream width would extend downstream past the Washington border. The State of Idaho cannot authorize a mixing zone that extends into another State. Thus, the conditions at the Washington border (191 meters downstream) are reported.
2. See discussion in Section 4.2.2.2 below.

4.2.2.2 Preventing Lethality to Aquatic Life Passing Through the Mixing Zone

The Idaho water quality standards state that mixing zones shall not cause unreasonable interference with or danger to beneficial uses. One of the effects that is considered to be "unreasonable interference with, or danger to" beneficial uses is "lethality to aquatic life passing through the mixing zone" (IDAPA 58.01.02.060.01.d.iv).

The EPA's Technical Support Document for Water Quality-based Toxics Control (TSD) (EPA 1991) includes recommendations for sizing mixing zones for acute water quality criteria, in order to prevent lethality to aquatic life passing through the mixing zone. The TSD states that "the use of a high-velocity discharge with an initial velocity of 3 meters per second, or more, together with a mixing zone spatial limitation of 50 times the discharge length scale in any direction, should ensure that the (acute criterion) is met within a few minutes under practically all conditions" (TSD Section 4.3.3~~2~~). The discharge length scale is defined as the square root of the cross-sectional area of any discharge outlet (TSD Page xx). The discharge velocity in this case is 6.34 meters per second.

Section 4.3.3 of the TSD also states that, if the discharge velocity is less than 3 meters per second, an acute mixing zone could be sized by meeting all of the following conditions:

- The CMC (criterion maximum concentration or acute criterion) should be met within 10 percent of the distance from the edge of the outfall structure to the edge of the regulatory mixing zone in any spatial direction.
- The CMC should be met within a distance of 50 times the discharge length scale in any spatial direction.
- The CMC should be met within a distance of five times the local water depth in any horizontal direction from any discharge outlet.

When the "Toxic Effluent" option is selected on the "Mixing Zone" tab in the Cormix input, Cormix will calculate and report the plume conditions consistent with the sizing criteria listed above~~at a distance of 50 times the discharge length scale, as well as other acute mixing zone sizing criteria from Section 4.3.2 of the TSD, which are applicable in cases where the discharge velocity is less than 3 meters per second~~.

In section 2.2.2, the TSD states that, "if a full analysis of concentrations and hydraulic residence times within the mixing zone indicates that organisms drifting through the plume along the path of maximum exposure would not be exposed to concentrations exceeding the acute criteria when averaged over the 1 -hour (or appropriate site-specific) averaging period for acute criteria, then lethality to swimming or drifting organisms ordinarily should not be expected, even for rather fast-acting toxicants. **In many situations, travel time through the acute mixing zone must be less than roughly 15 minutes if a 1-hour average exposure is not to exceed the acute criterion"** (emphasis added).

To determine the dilution provided by a mixing zone with a spatial limitation of 50 times the discharge length scale in any direction, the EPA set the discharge concentration equal to 100% and iteratively adjusted the ~~criterion maximum concentration (acute criterion)~~CMC specified in the Mixing Zone tab in increments of 0.01% until Cormix predicted that the toxic dilution zone (acute mixing zone) met this criterion. The scenario with the lowest edge-of-mixing zone concentration (or, equivalently, the largest dilution factor) that met the length scale criterion from the TSD yielded the following output:

```
************************ TOXIC DILUTION ZONE SUMMARY ************************
Recall: The TDZ corresponds to the three (3) criteria issued in the USEPA
  Technical Support Document (TSD) for Water Quality-based Toxics Control,
  1991 (EPA/505/2-90-001).
  Criterion maximum concentration (CMC)  = 11.630000  %
Corresponding dilution                   = 8.598452
The CMC was encountered at the following plume position:
  Plume location:                      x = 2.24 m
    (centerline coordinates)           y = -2.01 m
                                       z = 0.71 m
  Plume dimension:       half-width (bh) = 57.94 m
                          thickness (bv) = 0.60 m

 Computed distance from port opening to CMC location = 3.02 m.
```

```
CRITERION 1: This location is within 50 times the discharge length scale of
             Lq = 0.06 m.
+++++ The discharge length scale TEST for the TDZ has been SATISFIED. ++++++

Computed horizontal distance from port opening to CMC location = 3.01 m.
CRITERION 2: This location is within 5 times the ambient water depth of
             HD = 9.14 m.
++++++++++ The ambient depth TEST for the TDZ has been SATISFIED. ++++++++++

Computed distance from port opening to CMC location = 3.02 m.
CRITERION 3: This location is within one tenth the distance of the extent
             of the Regulatory Mixing Zone of 101.54 m in any
             spatial direction from the port opening.
+++++ The Regulatory Mixing Zone TEST for the TDZ has been SATISFIED. ++++++

The diffuser discharge velocity is equal to 6.34 m/s.
This exceeds the value of 3.0 m/s recommended in the TSD.

*** All three CMC criteria for the TDZ are SATISFIED for this discharge. ***
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Thus, an acute mixing zone providing a dilution factor of 8.60:1 would meet the length scale criterion from the TSD and would therefore prevent lethality to aquatic life passing through the mixing zone. It would also meet the criteria of being within 5 times the ambient water depth and ~~one tenth~~10% of the distance of the extent of the chronic mixing zone~~, although, according to the TSD, these criteria only apply in cases where the discharge velocity is less than 3 meters per second~~. That is to say, the length scale sizing criterion is the most restrictive, for this discharge.

As stated above, according to the TSD, a plume travel time "less than roughly 15 minutes" will ensure that the 1-hour average exposure of a swimming or drifting organism will not exceed the acute criterion. However, the plume travel time to reach an acute mixing zone sized based on the length scale criterion is only 4 seconds. Thus, in this case, an acute mixing zone that fails to meet the length scale criterion may nonetheless prevent lethality to passing organisms.

The EPA continued to adjust the CMC specified in the Mixing Zone tab until Cormix predicted that the TDZ met the criteria of 5 times the local water depth and 10% of the extent of the regulatory mixing zone, but did not meet the length scale criterion. The scenario with the largest dilution factor that met the criteria of 5 times the local water depth and 10% of the extent of the regulatory mixing zone, but did not meet the length scale criterion, yielded the following output:

```
************************ TOXIC DILUTION ZONE SUMMARY ************************
Recall: The TDZ corresponds to the three (3) criteria issued in the USEPA
  Technical Support Document (TSD) for Water Quality-based Toxics Control,
  1991 (EPA/505/2-90-001).
  Criterion maximum concentration (CMC)  = 6.7  %
Corresponding dilution                   = 14.925373
The CMC was encountered at the following plume position:
  Plume location:                       x = 7.50 m
    (centerline coordinates)            y = -6.76 m
                                        z = 1.31 m
  Plume dimension:       half-width (bh) = 52.27 m
                          thickness (bv) = 2.02 m
```

```
Computed distance from port opening to CMC location = 10.13 m.
CRITERION 1: This location is beyond 50 times the discharge length scale of
             Lq = 0.06 m.
+++++ The discharge length scale TEST for the TDZ has FAILED. ++++++

Computed horizontal distance from port opening to CMC location = 10.10 m.
CRITERION 2: This location is within 5 times the ambient water depth of
             HD = 9.14 m.
++++++++++ The ambient depth TEST for the TDZ has been SATISFIED. ++++++++++

Computed distance from port opening to CMC location = 10.13 m.
CRITERION 3: This location is within one tenth the distance of the extent
             of the Regulatory Mixing Zone of 101.54 m in any
             spatial direction from the port opening.
+++++ The Regulatory Mixing Zone TEST for the TDZ has been SATISFIED. ++++++

The diffuser discharge velocity is equal to 6.34 m/s.
This exceeds the value of 3.0 m/s recommended in the TSD.

*** This discharge DOES NOT SATISFY all three CMC criteria for the TDZ. ****
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The plume travel time to reach an acute mixing zone providing a dilution factor of 14.9:1 is 20.5 seconds.

Although an acute mixing zone providing a dilution factor of 14.9:1 does not meet the length scale criterion from Section 4.3.3 of the TSD, it does meet the criteria of being less than 5 times the local water depth in any horizontal direction and being less than 10% of the extent of the chronic mixing zone. Furthermore, the plume travel time is only 20.5 seconds, which is much less than the 15 minute recommendation in Section 2.2.2 of the TSD. Therefore, the EPA believes that an acute mixing zone providing a dilution factor of 14.9:1 would prevent lethality to aquatic life passing through the mixing zone, even though it would not meet the length scale criterion.

5 References

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